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14. ABSTRACT Electrochemistry in ambient temperature ionic liquids was performed. A portion of the work was carried out in haloaluminate melts, mainly 1-ethyl-3-ethyl imidazolium chloride - aluminum chloride. This was to complete work initiated under prior grants and involved studies of buffering of these systems. The bulk of the work involved electrochemical studies in non-haloaluminate ionic liquids, mainly 1-butyl-3-methylimidazolium hexafluorophosphate. Alkali metal reduction potentials were measured, an apparent anomaly with a rotating disc electrode was found and explained, and turn-on potentials and conductivities of polypyrrole films in the non-haloaluminate ionic liquids were measured.					
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Final Report on Grant No.F49620-00-1-0061
Studies in Buffered Chloroaluminate Ionic Liquids

This activity was funded from December 1, 1999 through January 31, 2004 for \$308,423. In addition, a supplement of \$30,545 was added from August 1, 2002 through January 31, 2004. This was added as a separate grant with the same title.

The Principal Investigator has been funded continuously since 1971, by AFOSR. He has been fortunate to have had incredibly capable Program Managers – Denton Elliott, John Wilkes, Hugh De Long, and Paul Trulove – who have allowed him to perform this work. He's also been fortunate to have had superb students and post-docs over the years, without whom none of the work carried out would have been done. Two of his graduate students were Air Force officers sent to do Ph.D. work in the molten salt area. Appendix A lists publications, which acknowledge AFOSR support since support was initiated in 1971. During the period of support, the PI has received several awards, which are listed in Appendix C. All are in part the result of the AFOSR support.

For the past several months, most of the effort has been devoted to winding down all laboratory work and cleaning up a laboratory that has had over 30 years of AFOSR support to amass chemicals and equipment. With the PI's retirement, the laboratory goes to other researchers.

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SUMMARY OF WORK, 1 December, 1999 – 31 January, 2004

Completed Work

I. Work Carried Out Under Previous Grant

Several manuscripts listed as "in press" or as "submitted" in the Final Report on Contract F49620-96-1-0097, "Studies of Latent Acidity and Neutral Buffered Chloroaluminate Ionic Liquids," have been published. These include:

Robert A. Osteryoung, "**Buffered Chloroaluminate Melts and Latent Acidity**," *Proceedings of the Twelfth International Symposium on Molten Salts*, P.C. Trulove, H. C. De Long, G. R. Stafford, and S. Deki, Eds., Proceedings Volume 99-41, pp. 12-19, The Electrochemical Society, Pennington, NJ (2000).

Diffusion Coefficients of Ferrocene in Composite Materials Containing Ambient Temperature Ionic Liquids, Marek Kosmulski, Robert A. Osteryoung, and Malgorzata Ciszewska, *J. Electrochem. Soc.*, **147**, 1454-1458 (2000).

Use of the Ag/AgCl/Cl⁻ Electrode to Estimate Solubility Products in Ambient Temperature Ionic Liquids, Peter Koronaios and Robert A. Osteryoung, *J. Electrochem. Soc.*, **147**, 3414-19 (2000).

II. Work Completed under Present Grant

Most of the work carried out under this present contract has been published, or is in press. Titles and Abstracts of the work follow.

A. Haloaluminate Ionic Liquids

Buffering of 1-Ethyl-3-Methylimidazolium Chloride/Aluminum Chloride Melts Using Alkali Metal Bromides and Halides, Peter Koronaios and Robert A. Osteryoung, *J. Electrochem. Soc.*, **148**, E483-488 (2001).

Abstract: The buffering of 1-ethyl-3-methyl imidazolium chloride (EMIC) – aluminum trichloride (AlCl₃) room-temperature ionic liquids (melts) using alkali metal bromides and iodides was studied. The bromide or iodide salts buffer the melts, but the bromide or iodide ions do not replace the chloride ions in the melts. Unlike melts buffered with alkali metal chlorides, it is relatively easy to deposit the alkali metals, and thus it may be possible to use these buffered melts in power sources. In melts buffered with a mixture of lithium chloride and iodide, it is possible to both deposit and strip lithium metal. As has been seen with melts buffered with alkali metal chlorides, the buffered melts appear to be more acidic than would be expected from the low concentration of the acidic Al₂Cl₇⁻ ion.

Robert A. Mantz, Hugh C. De Long, Robert A. Osteryoung, and Paul C. Trulove, "Studies of Cation Transport in Molten Salts and Molten Salt-Polymer Gels by Pulse-Field Gradient Spin-Echo NMR," *Proceedings of the Twelfth International Symposium on Molten Salts*, P.C. Trulove, H. C. De Long, G. R. Stafford, and S. Deki, Eds., Proceedings Volume 99-41, pp. 169-176, The Electrochemical Society, Pennington, NJ (2000).

Abstract: Pulsed-field-gradient spin-echo NMR has been used to determine the diffusion coefficients of the cation species in a series of chloroaluminate room-temperature molten salts as well as that of 1,2-dimethyl-3-propylimidazolium tetrafluoroborate and a molten salt polymer gel. Based on the diffusion coefficients, the activation energy for diffusion of the melt cations has been calculated. In addition, the hydrodynamic radius of the melt cation has been determined using the Stokes-Einstein relation.

B. Studies in Non-Haloaluminate Ionic Liquids

Electrochemical Properties of Alkali Metals in 1-Butyl-3-Methylimidazolium Hexafluorophosphates, Deborah L. Boxall and Robert A. Osteryoung, *J. Electrochem. Soc.*, **149**, E185-188 (2002).

Abstract: Formal potentials and diffusion coefficients of the alkali metal couples of lithium, sodium and potassium hexafluorophosphate salts dissolved in 1-butyl-3-methyl-imidazolium hexafluorophosphate were determined using a hanging mercury drop electrode as the working electrode. Chronoamperometry was used to determine the diffusion coefficients, which ranged from 1.4×10^{-8} to 4.5×10^{-8} cm²/s for the Na and K cations, respectively. Formal reduction potentials of -2.96 ± 0.006 V and -3.35 ± 0.003 V vs. the ferrocene/ferrocenium couple were obtained for sodium and potassium using normal pulse voltammetry. The presence of adsorption maxima in the lithium normal pulse voltammograms necessitated the use of chronopotentiometry to determine a lithium formal potential of -2.45 ± 0.025 V.

Apparent Anomaly During Rotating Disk Voltammetry in Ionic Liquids, Deborah L. Boxall, John J. O'Dea, and Robert A. Osteryoung, *J. Electrochem. Soc.*, **149**, E468-E471 (2002).

Abstract: An apparent anomaly is described in which maxima on rotating disk voltammograms for ferrocene oxidation in an ionic liquid were found. The ionic liquid, 1-butyl-3-methyl imidazolium hexafluorophosphate, bmimPF₆, is a neoteric solvent of current interest. The maxima are shown to be due to the very high viscosity of the solvent, 3.26 poise, which yields an unusually high Schmidt number of 3.5×10^7 , compared to a value of about 10^3 for aqueous solutions. It is estimated that over 100 revolutions of the disk are needed to achieve the Levich

limiting current following application of a voltage step to the disk. The current transient resulting from application of a voltage step to the rotating disk is found to be in agreement with previously developed theory, even for these highly viscous systems. Analysis of the transient permits a determination of the Schmidt numbers without measurement of the viscosity and density of the solvent, or diffusion coefficient of the reacting species.

Switching potentials and conductivity of polypyrrole films prepared in the ionic liquid 1-butyl-3-methylimidazolium hexafluorophosphate, Deborah L. Boxall and Robert A. Osteryoung, *J. Electrochem. Soc.*, **151**, E41-45 (2004).

Abstract: Polypyrrole (ppy) and poly(N-methylpyrrole) (pmPy) films were prepared galvanostatically at the ring of a rotating ring-disk electrode from the corresponding monomers dissolved in the ionic liquid 1-butyl-3-methylimidazolium hexafluorophosphate (bmimPF₆). Rotating ring-disk voltammetry was used to determine switching potentials and conductivity of the films while immersed in bmimPF₆. Switching potentials of 0.63 ± 0.04 V and 1.07 ± 0.03 V vs. the cobaltocenium/cobaltocene couple, [CoCp₂]⁺⁰, were determined for the ppy and pmPy films, respectively, from negative potential scan voltammograms. Positive potential scan voltammetry was used to obtain the potential dependent conductivity of the films as the films switched from their insulating (at potentials more negative than switching potential) to quasi-metallic state. Two different computational models (non-linear vs. linear conductance gradients) and two different redox probes ([CoCp₂]⁺⁰ and decamethylferrocenium/decamethylferrocene) were used in the calculation of film conductivity. The conductivity of the ppy films was found to increase by an order of magnitude for every 72 ± 8 mV change in the applied potential. At potentials less than the switching potential, the conductivity of the pmPy films increased ten-fold for every 110 ± 15 mV change in the applied potential. At potentials greater than the switching potential, the pmPy films required a 200 mV change to induce the same degree of change in film conductivity.

III. Personnel

Senior Research Personnel

Dr. Deborah Boxall
Dr. John O'Dea
Dr. Peter Koranaïos

APPENDIX A

Publications--Grant Related Activity - since AFOSR support initiated.

AFOSR-71-1955; 1 Jan. 1971 - 28 Feb. 1975

1. Janet Osteryoung and R. A. Osteryoung, "The Advantage of Charge Measurements for Determining Kinetic Parameters," *Electrochimica Acta*, 16, 525 (1971).
2. R. A. Osteryoung, "Introduction to the On-Line Use of Computers in Electrochemistry," Vol. II, "Application of Computers to Chemical Instrumentation," Ed. by Mattson, Mark and MacDonald, Marcel Dekker (1973).
3. L. G. Boxall, H. L. Jones and R. A. Osteryoung, "Solvent Equilibria in AlCl_3 -NaCl Melts," *J. Electrochem. Soc.*, 120(2), 223 (1973).
4. H. Lloyd Jones, L. G. Boxall and R. A. Osteryoung, "Organic Electrode Reactions in Fused AlCl_3 Containing Solvents," *J. Electroanal. Chem.*, 38, 476 (1972).
5. L. G. Boxall, H. L. Jones and R. A. Osteryoung, "Electrochemical Studies on Ag, Fe and Cu Species in AlCl_3 -NaCl Melts," *J. Electroanal. Chem.*, 121, 212 (1974).
6. H. Lloyd Jones and R. A. Osteryoung, "Electrode Reactions of Aromatic Amines in Solvents Containing Fused AlCl_3 :II., " *J. Electroanal. Chem.*, 49, 281 (1974).
7. R. J. Gale and R. A. Osteryoung, "Investigation of Subvalent Ion Effects During Aluminum Anodization in Molten NaCl- AlCl_3 Solvents," *J. Electrochem. Soc.*, 121, 983 (1974).
8. V. R. Koch, L. L. Miller and R. A. Osteryoung, "Reductive Defunctionalization of 1-substituted Adamantanes in Molten Sodium Tetrachloroaluminate," *J. Org. Chem.*, 39, 2416 (1974).
9. H. Lloyd Jones and R. A. Osteryoung, "Organic Reactions in Molten Tetrachloroaluminate Solvents," *Advances in Molten Salt Chemistry*, Vol. 3, Edited by J. Braunstein, G. P. Smith and G. Mamantov, Plenum Publishing (1975).
10. R. J. Gale and R. A. Osteryoung, "Dissociative Chlorination of Nitrogen Oxides and Oxyanions in Molten Sodium Chloride-Aluminum Chloride Solvent," *Inorg. Chem.*, 14, 1232 (1975).
11. H. L. Chum, V. R. Koch, L. L. Miller and R. A. Osteryoung, "An

Electrochemical Scrutiny of Organometallic Iron Complexes and Hexamethylbenzene in a Room Temperature Molten Salt," J. Am. Chem. Soc., 97, 3264 (1975).

12. D.E. Bartak and R. A. Osteryoung, "The Electrochemical Oxidation of N,N,N',N'-Tetramethylbenzidine in Molten Sodium Tetrachloroaluminate," J. Electrochem. Soc., 122, 600 (1975).
13. J. Phillips, R. J. Gale, R. G. Wier and R. A. Osteryoung, "Glassy Carbon Rotating Ring-Disc Electrodes for Molten Salt Studies," Anal Chem., 48, 1266 (1976).
14. D. E. Bartak and R. A. Osteryoung, "The Redox Behavior of Tetrachloro-p-Benzoquinone-Tetrachlorohydroquinone Systems in Molten Aluminum Chloride-Sodium Chloride Solvents," J. Electroanal. Chem., 74, 69 (1976).

AFOSR 75-2776; 1 March 1975 - 31 May 1976

15. V. R. Koch, L. L. Miller and R. A. Osteryoung, "Electroinitiated Friedel-Crafts Transalkylations in a Room Temperature Molten Salt Media," J. Am. Chem. Soc., 98, 5377 (1976).
16. K. A. Paulsen and R. A. Osteryoung, "Electrochemical Studies on Sulfur and Sulfides in AlCl₃-NaCl Melts," J. Am. Chem. Soc., 98, 6866 (1976).
17. R. A. Osteryoung, "Chemistry and Electrochemistry in Aluminum Chloride Molten Salt Systems," Proceedings of the Symposium on Molten Salts, edited by J. P. Pemsler, J. Braunstein, K. Nobe, D. R. Morris, pp. 240-253, The Electrochemical Society, Pennington, NJ (1976).

AFOSR 766-2978; 1 April 1976 - 30 June, 1979

18. J. Phillips and R. A. Osteryoung, "Molybdenum Chemistry in NaCl-AlCl₃ Melts at 175°C," J. Electrochem. Soc., 124, 1405 (1977).
19. J. Robinson, B. Gilbert and R. A. Osteryoung, "The Acid-Base Chemistry of Oxide and Chalcogenides in Sodium Tetrachloroaluminate Melts at 175°C," Inorg. Chem., 16, 3040 (1977).
20. Helena Li Chum, T. Rabockai, J. Phillips and R. A. Osteryoung, "Ligand Oxidation in Iron Diimine Complexes. III. Electrochemical Oxidation of tris-(glyoxalbis(methylimine))Iron(II)," Inorg. Chem., 16, 1812 (1977).
21. Helena Li Chum, D. Koran and R. A. Osteryoung, "The Electrochemical Behavior of Metal Carbonyls in a Mixture of a Room Temperature Molten Salt and Benzene," J. Organometallic Chem., 140, 349 (1977).

22. Helena Li Chum, D. Koran and R. A. Osteryoung, "Photochemistry of Iron(II)Diimine Complexes in a Room Temperature Molten Salt," J. Am. Chem. Soc., 100, 310 (1978) .
23. J. Robinson and R. A. Osteryoung, "Electrochemical Studies of Selenium and Selenium Compounds in Molten Sodium Tetrachloroaluminate Melts," J. Electrochem. Soc., 125, 1454 (1978).
24. B. Gilbert and R. A. Osteryoung, "Electrochemical Studies on Nickel Electrodes in Molten Sodium Tetrachloroaluminates," J. Am. Chem. Soc., 100, 2725 (1978).
25. Gleb Mamantov and R. A. Osteryoung, "Acid-Base Dependent Redox Chemistry in Molten Chloroaluminates," in "Characterization Of Solutes in Non-Aqueous Solutions," pg 225-250, G. Mamantov, Ed., Plenum Publishing Co. (1977).
26. R. J. Gale, B. Gilbert and R. A. Osteryoung, "Raman Spectra of Molten Aluminum Chloride: 1 Butylpyridinium Chloride Systems at Ambient Temperature," Inorg. Chem., 17, 2728 ~978).
27. J. Robinson and R. A. Osteryoung, "The Electrochemical Behavior of Te(IV) in Sodium Tetrachloroaluminates," J. Electrochem. Soc., 125, 1784 (1978).
28. J. Robinson and R. A. Osteryoung, "The Electrochemical and Spectroscopic Behavior of Some Aromatic Hydrocarbons in the Room Temperature Molten Salt System AlCl₃:n-Butylpyridinium Chloride," J. Am. Chem. Soc., 101, 321 (1978) .
29. J. Robinson, R. C. Bugle, H. L. Chum, D. Koran and R. A. Osteryoung, ¹H and ¹³C Nuclear Magnetic Resonance Spectroscopy Studies of Aluminum Halide-Alkyl Pyridinium Halide Molten Salts and Their Benzene Solutions," J. Am. Chem. Soc., 101, 3776 (1979).
30. R. J. Gale and R. A. Osteryoung, "Potentiometric Investigation of Dialuminum Heptachloride Formation in Aluminum Chloride: 1-butylpyridinium Chloride Mixtures," Inorg. Chem., 18, 1603 (1979).

AFOSR F49620-79-C-0142: 1 June 1979 - 30 Sept. 1980

31. J. Robinson and R. A. Osteryoung, "The Electrochemical Behavior of Aluminum in the Low Temperature Molten Salt System n-Butyl Pyridinium Chloride; Aluminum Chloride and Mixtures of this Molten Salt with Benzene," J. Electrochem. Soc., 127, 122 (1980).
32. J. Robinson and R. A. Osteryoung, "An Investigation into the Electrochemical Oxidation of Some Aromatic Amines in the Room Temperature Molten Salt

System AlCl_3 :N-Butylpyridinium Chloride," J. Am. Chem. Soc., 102, 4415 (1980).

33. R. J. Gale and R. A. Osteryoung, "Electrochemical Reduction of Pyridinium Ions in Ionic Aluminum Chloride-Alkylpyridinium Halide Ambient Temperature Liquids," J. Electrochem.Soc., 127, 2167 (1980).
34. R. J. Gale and R. A. Osteryoung, "Electrical Double Layer at Mercury in Room Temperature Aluminum Chloride- Butylpyridinium Chloride Ionic Liquids," Electrochemica Acta, 25, 1527 (1980).
35. R. J. Gale and R. A. Osteryoung, "Infrared Spectral Investigations of Ambient Molten Aluminum Chloride:-1-Butylpyridinium Chloride Systems," Inorg. Chem., 19, 2240 (1980).
36. Janet Osteryoung and Emilia Kirowa-Eisner, "Reverse Pulse Polarography," Anal. Chem., 52, 62-66 (1980).
37. Koichi Aoki, R. A. Osteryoung and Janet Osteryoung, "Differential Normal Pulse Voltammetry," J. Electroanal. Chem.,110, 1-18 (1980).

AFOSR-81-0007; 1 October, 1980 - 31 August, 1984

38. B. J. Welch and R. A. Osteryoung, "Electrochemical Studies in Low Temperature Molten Salt Systems Containing Aluminum Chlorides," J. Electroanal. Chem., 118, 455-466 (1981).
39. Z. Stojek, H. Linga and R. A. Osteryoung, "A Titration Procedure for the Determination of Oxide in Basic n-Butylpyridinium Chloride: Aluminum Chloride Melts," J. Electroanal. Chem., 119, 365-70 (1981).
40. H. Linga, Z. Stojek and R. A. Osteryoung, "Electrochemistry of Titanium(III) in Basic n-Butylpyridinium Chloride and Aluminum Chloride in Presence of Oxide," J. Am. Chem. Soc., 103, 3754 (1981).
41. Helena Li Chum, D. Koran and R. A. Osteryoung, "Substituent Effects in Iron Diimine Complexes: Correlations with Thermodynamic Properties in a Room Temperature Molten Salt," Inorg. Chem., 20, 3304-3307 (1981).
- *42. T. R. Brumleve, John J. O'Dea, Robert Osteryoung and Janet Osteryoung, "Differential Normal Pulse Voltammetry in the Alternate Pulse Mode Reversible Electrode Reactions," Anal. Chem., 53, 702 (1981).
- *43. T. R. Brumleve and Janet Osteryoung, "Theory of Differential Normal Pulse Voltammetry in the Alternating Pulse Mode for Totally Irreversible Electrode Reactions," Anal. Chem., 53, 988-991 (1981).

- *44. T. R. Brumleve, R. A. Osteryoung and Janet Osteryoung, "Differential Normal Pulse Voltammetry for the Anodic Oxidation of Iron(II); Anal. Chem., 54, 782-787 (1982).
- *45. T. R. Brumleve and Janet Osteryoung, "Spherical Diffusion and Shielding Effects in Reverse Pulse Voltammetry," J. Phys. Chem., 86, 1794-1801 (1982).
- 46. G. T. Cheek and R. A. Osteryoung, "Electrochemical and Spectroscopic Studies of 9,10-Anthraquinone in a Room Temperature Molten Salt," J. Electrochem. Soc., 129, 2488 (1982).
- 47. C. Nanjundiah, K. Shimizu and R. A. Osteryoung, "Electrochemical Studies of Fe(II) and Fe(III) in an Aluminum Chloride-Butylpyridinium Chloride Ionic Liquid," J. Electrochem. Soc., 129, 2474 (1982).
- 48. G. T. Cheek and R. A. Osteryoung, "Preparation and Characterization of a Substituted Alkylpyridinium Chloroaluminate Molten Salt System," Inorg. Chem., 21, 3581 (1982).
- 49. G. T. Cheek and R. A. Osteryoung, "An Electrochemical and Infra-red Study of Chloranil in n-Butylpyridinium Chloride:Aluminum Chloride Ionic Liquid," J. Electrochem. Soc., 129, 2739 (1982).
- 50. Chenniah Nanjundiah and R. A. Osteryoung, "Electrochemical Studies of Cu(I) and Cu(II) in an Aluminum Chloride-N-(n-Butylpyridinium) Chloride Ionic Liquid," J. Electrochem. Soc., 130, 1312 (1983).
- 51. Saeed Sahami and R. A. Osteryoung, "Voltammetric Determination of Water in an Aluminum Chloride-N-n-Butylpyridinium Chloride Ionic Liquid," Anal. Chem., 55, 1970 (1983).

*Work related to pulse methodology development but not supported by A.F.O.S.R.

- 52. Z. Karpinski and R. A. Osteryoung, "Electrochemical Studies of Iodine in an Aluminum Chloride-Butylpyridinium Chloride Ionic Liquid. I. Acidic Solvent Composition," J. Electroanal. Chem., 164, 281 (1984).
- 53. D. A. Habboush and R. A. Osteryoung, "Electrochemical Studies of Sb(III) and Sb(V) in Molten Mixtures of Aluminum Chloride and Butylpyridinium Chloride," Inorg. Chem., 23, 1726 (1984).
- 54. R. A. Osteryoung, R. J. Gale, J. Robinson, R. Bugle and B. Gilbert, "Electrochemical Studies in Room Temperature Molten Salts," in "Proceedings of the Second International Symposium on Molten Salts," J. Braunstein and R. Selman, eds., pg. 214-219, The Electrochemical Society, Pennington, NJ (1981).

55. R. A. Osteryoung, G. Cheek and H. Linga, "Studies in Room Temperature Chloroaluminates," in "Proceedings of the Third International Symposium on Molten Salts," G. Mamantov, ed., pg. 221-236, The Electrochemical Society, Pennington, NJ (1981).
56. C. Nanjundiah, K. Shimizu and R. A. Osteryoung, "Electrochemical Studies in an Aluminum Chloride-Butylpyridinium Chloride Ionic Liquid" in "Proceedings of the Workshop on Thermally Regenerative Electrochemical Systems," SERI/CP-234-1577, Solar Energy Research Institute, Golden, Colorado (1982).
57. H. L. Chum and R. A. Osteryoung, "Chemical and Electrochemical Studies in Room Temperature Aluminum Halide Containing Melts," in "Ionic Liquids," D. Inman and D. Lovering, eds., pg. 407-423, Plenum Press, London (1981).
58. R. J. Gale and R. A. Osteryoung, "High and Room Temperature Haloaluminates," in "Molten Salt Techniques," D. Lovering and R. J. Gale, eds., Ch. 3, pgs 55-78, Plenum Press, New York (1983).
59. G. T. Cheek and R. A. Osteryoung, "Preparation and Characterization of a Substituted Alkylpyridinium Chloroaluminate Molten Salt System," *Inorg. Chem.*, 21, 3581 (1982).
60. M. Lipsztajn and R. A. Osteryoung, "Increased Electrochemical Window in Ambient Temperature Ionic Ionic Liquids," *J. Electrochem. Soc.*, 130, 1968 (1983).
61. M. Lipsztajn and R. A. Osteryoung, "Reactions of Chloride Ions in Low Temperature Molten Salt and Applications to the Study of Complex Ion Stoichiometry," *Inorg. Chem.*, 23, 1735 (1984).
62. Z. Karpinski and R. A. Osteryoung, "On Determination of Equilibrium Constants for the Tetrachloroaluminate Dissociation in Ambient Temperature Ionic Liquids," *Inorg. Chem.*, 23, 1491 (1984).
63. P. G. Pickup and R. A. Osteryoung, "Polymer Coated Electrodes in Ambient Temperature Ionic Liquids," *J. Electrochem. Soc.*, 130, 1965 (1983).
64. S. Sahami and R. A. Osteryoung, "Electrochemical and Spectroscopic Studies of Polypyridine Complexes of Fe(II)/(III) and Ru(II)/(III) in the Aluminum Chloride N-(1-Butyl)pyridinium Chloride Molten Salt System," *Inorg. Chem.*, 23, 2511 (1984).
65. P. G. Pickup and R. A. Osteryoung, "Electrochemical Polymerization of Pyrrole and Electrochemistry of Polypyrrole Films in Ambient Temperature Molten Salts," *J. Am. Chem. Soc.*, 106, 2294 (1984).

66. P. G. Pickup and Robert A. Osteryoung, Charging and Discharging Rate Studies of Polypyrrole Films in AlCl_3 :1-Methyl-(3-Ethyl)-Imidazolium Chloride Molten Salts and in CH_3CN " J. Electroanal. Chem., 195, 271 (1985).
67. P. G. Pickup and Robert A. Osteryoung, Charge Transport in Poly-[$\text{Ru}(2,2'\text{-Bipyridine})(4\text{-Vinylpyridine})$] $^{3+/2+}$ Films in AlCl_3 /N-(1-Butyl)pyridinium Chloride and AlCl_3 /1-Methyl(3-Ethyl)imidazolium Chloride Molten Salts" J. Electroanal. Chem., 186, 99 (1985).
68. P. G. Pickup and R. A. Osteryoung, "Electrochemistry and Spectroelectrochemistry in CH_3CN and Aluminum Chloride/N-(1-Butyl)pyridinium Chloride Molten Salts of Films Prepared by Electrochemical Polymerization of Tris(5-amino-1,10-phenanthroline)Iron (II)," Inorg. Chem., 24, 2707 (1985).
69. L. Janiszewska and R. A. Osteryoung, "Electrochemistry of Polythiophene and Polybithiophene Films in Ambient Temperature Molten Salts," J. Electrochem. Soc., 134, 2787 (1987).
70. M. Lipsztajn and R. A. Osteryoung, "Electrochemical Reduction of N-(1-Butyl)Pyridinium Cation in 1-Methyl-3-Ethyl-Imidazolium Chloride-Aluminum Chloride Ambient Temperature Ionic Liquids," Electrochim. Acta, 29, 1349 (1984).
71. M. Lipsztajn and R. A. Osteryoung, "Electrochemistry in Neutral Ambient Temperature Ionic Liquids. Part I. Studies of Iron(III), Neodymium(III) and Lithium(I)," Inorg. Chem., 24, 716 (1985).
72. M. Lipsztajn and R. A. Osteryoung, "Studies of Antimony(III) in Ambient Temperature Ionic Liquids," Inorg. Chem., 24, 3492 (1985).
73. M. Lipsztajn, S. Sahami and R. A. Osteryoung, "Hydroquinone as a Proton Donor in Ambient Temperature Chloroaluminate Ionic Liquids: Reaction with Chloride Ion," Inorg. Chem., 25, 549 (1986).
74. Z. Karpinski, C. Nanjundiah and R. A. Osteryoung, "Electrochemical Studies of Ferrocene and Ferrocenium Ion in Liquid," Inorg. Chem., 23, 3358 (1984).
75. Z. Karpinski and R. A. Osteryoung, "Electrochemical Studies of Iodine in an Aluminum Chloride-Butylpyridinium Chloride Ionic Liquid: Part II. Neutral and Basic Solvent Composition," J. Electroanal. Chem., 178, 281 (1984).

76. Z. Karpinski and R. A. Osteryoung, "Spectrophotometric Studies of Iodine Complexes in an Aluminum Chloride-Butylpyridinium Chloride Ionic Liquid," *Inorg. Chem.*, 23, 4561 (1984).
77. Z. Karpinski and R. A. Osteryoung, "Potentiometric Studies of the Chlorine Electrode in Ambient Temperature Chloroaluminate Ionic Liquids: Determination of Equilibrium Constants for Tetrachloroaluminate Ionic Dissociation," *Inorg. Chem.*, 24, 2259 (1985).
78. S. Sahami and R. A. Osteryoung, "Electrochemical Oxidation of Some Metal Carbonyls in Ambient Temperature Ionic Liquids," *Electrochim. Acta*, 30, 143 (1985).
79. M. Lipsztajn and R. A. Osteryoung, "On Ionic Association in Ambient Temperature Chloroaluminate Molten Salts: Analysis of Electrochemical and Conductance Data," *J. Electrochem. Soc.*, 132, 1126 (1985).
80. T. A. Zawodzinski, Jr., R. Kurland and R. A. Osteryoung, "Relaxation Time Measurements in N-(1-Butyl)pyridinium-Aluminum Chloride Ambient Temperature Ionic Liquids," *J. Phys. Chem.*, 91, 962 (1987).
81. Robert A. Osteryoung, "Organic Chloroaluminate Ambient Temperature Molten Salts" in Molten Salt Chemistry: An Introduction and Selected Applications, G. Mamantov and R. Marassi, Eds., Pgs. 329-364, NATO ASI Series C: Mathematical and Physical Sciences, Vol. 202, D. Reidel Publishing Co., Dordrecht, Boston, (1987) .

AFOSR-87-0088; 1 December, 1986 - 30 November, 1989

82. T. A. Zawodzinski, Jr. and R. A. Osteryoung, "Aspects of the Chemistry of Water in Ambient Temperature Chloroaluminate Ionic Liquids: ^{17}O NMR Studies," *Inorg. Chem.*, 26, 2920 (1987).
83. T. A. Zawodzinski, Jr. and R. A. Osteryoung, "The Chemistry of Water in Ambient Temperature Chloroaluminate Ionic Liquids: NMR Studies" in *Proceedings of the Joint International Symposium on Molten Salts*, G. Mamantov et al., Eds., Vol. 87-7, pp. 406-413, The Electrochemical Society, Pennington, NJ (1987) .
84. T. A. Zawodzinski, Jr., R. Carlin and R. A. Osteryoung, "Removal of Protons from Chloroaluminate Ionic Liquids," *Anal. Chem.*, 59, 2639 (1987).
85. L. Janiszewska and R. A. Osteryoung, "Investigations on the Formation of Polyfluorene and Its Electrochemistry in Ambient Temperature Ionic Liquids," *J. Electrochem. Soc.*, 135, 116 (1988).

86. F. Uribe and R. A. Osteryoung, "Electrochemical and Spectroscopic Studies of 1,4-Benzoquinone in Ambient Temperature Chloroaluminate Molten Salts," *J. Electrochem. Soc.*, 135, 378 (1988).
87. J. F. Oudard, R. Allendoerfer and R. A. Osteryoung, "Simultaneous EPR Electrochemical and Spectroscopic Studies in Ambient Temperature Ionic Liquids," *J. Electroanal. and Interfac. Chem.*, 241, 231 (1988).
88. J. F. Oudard, R. Allendoerfer and R. A. Osteryoung, "Simultaneous EPR Electrochemical Measurements on Polyfluorene in Ambient Temperature Ionic Liquids," *Synth. Met.*, 22, 407 (1988).
89. R. Carlin and R. A. Osteryoung, "Electrochemistry of Molybdenum Chloride Dimers in a Basic Ambient Temperature Molten Salt," *Inorg. Chem.*, 27, 1483 (1988).
90. Lin Sinru, J. J. O'Dea, J. Osteryoung and R. A. Osteryoung, "Normal and Reverse Pulse Voltammetry at Microdisc Electrodes," *Anal. Chem.*, 60, 1135 (1988).
91. Lin Sinru and R. A. Osteryoung, "Normal and Reverse Pulse Voltammetry from Poised Systems at Microdisk Electrodes," *Anal. Chem.*, 60, 1845 (1988).
92. R. Carlin and R. A. Osteryoung, "Reactions of Protons and Molybdenum Dimers in an Ambient Temperature Molten Salt," *Inorg. Chem.*, 27, 3675 (1988).
93. R. Carlin and R. A. Osteryoung, "Microelectrodes in the Examination of Anodic and Cathodic Limit Reactions of an Ambient Temperature Molten Salt," *J. Electroanal. and Interfac. Chem.*, 252, 81 (1988).
94. T. A. Zawodzinski, Jr. and R. A. Osteryoung, "1-Methyl-3-Ethylimidazolium Hydrogen Bichloride: Synthesis and Application to the Study of Protons in Ambient Temperature Chloroaluminate Ionic Liquids," *Inorg. Chem.*, 27, 4383 (1988).
95. T. A. Zawodzinski, Jr., L. Janiszewska and R. A. Osteryoung, "On the Chemistry of Pyrrole in Room Temperature Chloroaluminate Melts," *J. Electroanal. and Interfac. Chem.*, 255, 111, (1988).
96. B. Das, R. T. Carlin and R. A. Osteryoung, "The Ferro/Ferricyanide Couple in Aluminum Chloride-Imidazolium Chloride Ambient Temperature Molten Salts," *Inorg. Chem.*, 28, 421 (1989).
97. T. A. Zawodzinski, Jr. and R. A. Osteryoung, "Donor-Acceptor Properties of Ambient Temperature Chloroaluminate Melts," *Inorg. Chem.*, 28, 1710 (1989).
- *98. R. Carlin and R. A. Osteryoung, "Aluminum Anodization in Basic Ambient

Temperature Molten Salts," J. Electrochem. Soc., 136, 1409 (1989).

AFOSR 90-0099; 1 December, 1989 - 30 June, 1992

- *99. R. T. Carlin and R. A. Osteryoung, "Deposition Studies of Lithium and Bismuth at Tungsten Microelectrodes in LiCl:KCl Eutectic," J. Electrochem. Soc., 136, 1249-1255 (1989).
- 100. Thomas A. Zawodzinski, Jr. and R. A. Osteryoung, "Donor Acceptor Properties of Ambient-Temperature Chloroaluminate Melts," Inorg. Chem., 28, 1710-1715 (1989).
- 101. P. C. Trulove, R. T. Carlin, and R. A. Osteryoung, "Lewis and Bronsted Acid Adducts in Ambient Temperature Chloroaluminate Molten Salts," J. Am. Chem. Soc., 112, 4567-4568 (1990).
- 102. Marc A. M. Noël and Robert A. Osteryoung, "Determination of the Stoichiometry of Some Metal Chlorocomplex Ions in Basic Ambient Temperature Molten Salts," J. Electroanal. Chem., 284, 413-429 (1990).
- * Work relevant to this grant but supported in part by SDIO/IST, managed by ONR.
- 103. Thomas A. Zawodzinski, Jr. and R. A. Osteryoung, "Oxide and Hydroxide Species Formed on Addition of Water in Ambient Temperature Chloroaluminate Melts: An ^{17}O NMR Study," Inorg. Chem., 29, 2842-2847 (1990).
- 104. R. T. Carlin, R. A. Osteryoung, J. S. Wilkes and J. Rovang, "Studies of Titanium(IV) Chloride in a Strongly Lewis Acidic Molten Salt: Electrochemistry, Titanium NMR and Electronic Spectroscopy," Inorg. Chem., 29, 3003-3009 (1990).
- 105. Marc Noël and R. A. Osteryoung, "Use of Metal Chlorides to Buffer Neutral Ambient Temperature Molten Salts," J. Electroanal. Chem., 293, 108, 139-150 (1990).
- 106. Basudev K. Das and Robert A. Osteryoung, Electrochemistry of 9,10-Anthraquinone Moiety of [1-Pyrrol-1-YL)-HEX-6-YL]-9,10-Anthraquinone-2-Sulfonate in Aluminum Chloride-1-Methyl-3-Ethylimidazolium Chloride Ambient Temperature Melt, J. Bangladesh Chem. Soc., 3(2), 147-152 (1990).
- 107. Soo-Gil Park, Paul C. Trulove, Richard T. Carlin and Robert A. Osteryoung, "A Mixed Lewis Acid-Bronsted Acid Ambient Temperature Ionic Liquid: An Electrochemical and NMR Study of Dimethylaniline," J. Am. Chem. Soc., 113, 3334-3340 (1991).
- 108. Michael T. Carter, Charles L. Hussey, S. K.D. Strubinger, and Robert A. Osteryoung, "Electrochemical Reduction of Dioxygen in Room-Temperature

Imidazolium Chloride-Aluminum Chloride Molten Salts," *Inorg. Chem.*, 30, 1149-1151 (1991).

- *109. Renewal of Boundary Conditions in Pulse Voltammetry at Microdisk Electrodes for Non-Reversible Systems, Z. J. Karpinski and Robert A. Osteryoung, *J. Electroanal. Chem.*, 307, 47-62 (1991).
- 110. J. Tang and R. A. Osteryoung, "Electrochemistry of Polyaniline in Ambient Temperature Molten Salts: I," *Syn. Met.*, 44, 307-319 (1991).
- 111. J. Tang and R. A. Osteryoung, "Formation and Electrochemistry of Polyaniline in Ambient Temperature Molten Salts," *Syn. Met.*, 45, 1-13 (1991).
- * Work relevant to this grant but supported in part by NSF
- 112. P. Trulove, M. Noel and R. A. Osteryoung, "Removal of Protons from Ambient-Temperature Chloroaluminate Ionic Liquids," *Anal. Chem.*, 63, 2892-2896 (1991).
- 113. Marc A.M. Noel, R. Allendoerfer, and R. A. Osteryoung, "Solvation in Ionic Liquids: An EPR Study," *J. Phys. Chem.*, 96, 2391-2394 (1992).
- 114. J. Tang, R. Allendoerfer and R. A. Osteryoung, "Simultaneous EPR and Electrochemical Measurements on Polyaniline in Ambient Temperature Molten Salts," *J. Phys. Chem.*, 96, 3531-3536 (1992).
- 115. Marc A.M. Noel, John J. O'Dea, and R. A. Osteryoung, "Short Time Pulse Voltammetry at Very Small Electrodes in Ambient Temperature Chloroaluminate Ionic Liquids," *J. Electrochem. Soc.*, 139, 1231 -1236 (1992).
- 116. P. C. Trulove, R. T. Carlin and R. A. Osteryoung, "Interaction of Protons with Solutes in Ambient Temperature Chloroaluminate Molten Salts: Electrochemistry and NMR Spectroscopy of Protonated Anthracene," *Proceedings of the Seventh International Symposium on Molten Salts*, C. L. Hussey, S. N. Flengas, J. S. Wilkes and Y. Ito, Eds, The Electrochemical Society, Proceedings Volume 90-17, pgs. 306-324, Pennington, NJ (1990).
- 117. S. G. Park, P. Trulove, R. T. Carlin and R. A. Osteryoung, "Protons in Ambient Temperature Chloroaluminate Molten Salts: Electrochemical and NMR Studies of Their Interaction with Dimethylaniline," *Proceedings of the Seventh International Symposium on Molten Salts*, C. L. Hussey, S. N. Flengas, J. S. Wilkes and Y. Ito, Eds, The Electrochemical Society, Proceedings Volume 90-17, pgs. 290-305, Pennington, NJ (1990).
- 118. Michael T. Carter and Robert A. Osteryoung, "Electrochemistry of 9,10-Anthraquinone in the Presence of Proton and Tetrachloroaluminate in Ambient Temperature Molten Salts," *Proceedings of Eighth International Symposium on Molten Salts*, R. J. Gale, George Blomgren, and H. Kojima,

Eds., The Electrochemical Society, Proceedings Volume 92-16, pgs. 406-425, Pennington, NJ, (1992).

119. Paul C. Trulove and Robert A. Osteryoung, "The Nature of Proton in Ambient-Temperature Chloroaluminate Molten Salts," Proceedings of Eighth International Symposium on Molten Salts, R. J. Gale, George Blomgren, and H. Kojima, Eds., Proceedings Volume 92-16, pgs. 292-302, The Electrochemical Society, Pennington, NJ, (1992).
120. Paul C. Trulove and Robert A. Osteryoung, "The Chemistry of Proton in Ambient Temperature Chloroaluminate Molten Salts," Proceedings of Eighth International Symposium on Molten Salts, R. J. Gale, George Blomgren, and H. Kojima, Eds., Proceedings Volume 92-16, pgs. 303-316, The Electrochemical Society, Pennington, NJ, (1992).

AFOSR Grant F49620-92-J-0326: 1 July, 1992 - 31 December, 1993

121. Richard Carlin, Paul Trulove and Robert A. Osteryoung, "Electrochemical and Spectroscopic Study of Anthracene in a Mixed Lewis-Brønsted Acid Ambient Temperature Molten Salt System," *Electrochim. Acta*, 37, 2615-2628 (1992).
122. Jinsong Tang, Kunio Shimizu and Robert A. Osteryoung, "Electrochemical Studies of Tris-(acetylacetonato)ruthenium(III) Complex in Ambient Temperature Chloroaluminate Molten Salts," *Inorg. Chem.*, 31, 3980-3985 (1992).
123. Michael Carter and Robert A. Osteryoung, "Interaction of 9,10-Anthraquinone with Tetrachloroaluminate and Proton in Basic Aluminum Chloride:1-Ethyl-3-Methylimidazolium Chloride Room Temperature Molten Salts," *J. Electrochem. Soc.*, 139, 1795-1802 (1992).
124. Paul C. Trulove and Robert A. Osteryoung, "Proton Speciation in Ambient Temperature Chloroaluminate Ionic Liquids," *Inorg. Chem.*, 31, 3980-3985 (1992).
125. Paul C. Trulove, Dinesh K. Sukumaran, and Robert A. Osteryoung, "NMR Studies of the Proton Equilibrium in Basic Ambient-Temperature Chloroaluminate Ionic Liquids," *Inorg. Chem.*, 32, 4396 (1993).
126. S. Song, J. Tang, M. Kajitani, K. Shimizu, and Robert A. Osteryoung, "Electrode Processes of (η^5 -Cyclopentadienyl)-(1,2-Substituted 1,2-Ethylenedithiolato)Cobalt(III) Complexes in an Ambient Temperature Molten Salt," *J. Chem.*, 455, 211-217 (1993).
127. Richard T. Carlin and Robert A. Osteryoung, "A Silane-Based Electroactive Film Prepared in Imidazolium Chloroaluminate Molten Salt," *J. Electrochem. Soc.*, 141, 1709-1713 (1994).
128. Z. J. Karpinski, S. Song and R. A. Osteryoung, "Dependence of Electron Transfer Kinetics of the Ferrocene/Ferrocenium Couple on the Viscosity in Ambient Temperature Chloroaluminate Ionic Liquids," *Inorg. Chim. Acta*, 225, 9-14 (1994).

129. Leonid Goldenberg and Robert A. Osteryoung, "Benzene Polymerization in 1-Ethyl-3-Methylimidazolium Chloride- AlCl_3 Ionic Liquid," *Syn. Met.*, **64**, 63-68 (1994).

AFOSR Contract F49620-94-1-0056, 1 January, 1994 - 30 June, 1996.

130. Michael T. Carter and Robert A. Osteryoung, "Heterogeneous and Homogeneous Electron Transfer Reactions of Tetrathafulvalene in Ambient Temperature Chloroaluminate Molten Salts," *J. Electrochem. Soc.*, **141**, 1713-1720 (1994).
131. I. C. Quarmby, R. A. Mantz, L. M. Goldenberg, and R. A. Osteryoung, "Examination of the Stoichiometry of Latent Acidity in Buffered Chloroaluminate Ionic Liquids," *Anal. Chem.*, **66**, 3558-3561 (1994).
132. I. C. Quarmby, R. A. Mantz, L. M. Goldenberg, and R. A. Osteryoung, "Latent Acidity in Buffered Chloroaluminate Ionic Liquids," *Proceedings of Ninth International Symposium on Molten Salts*, C. Hussey, D. Newman, G. Mamantov, and Y. Ito, Eds., *Proceedings Volume 94-13*, pgs. 483-490, The Electrochemical Society, Pennington, NJ (1994).
133. Robert A. Mantz, R. A. Osteryoung, Paul C. Trulove, Richard T. Carlin and Hanna Sierzputowska-Gracz, "ROESY NMR of Basic Ambient Temperature Chloroaluminate Ionic Liquids," *Proceedings of Ninth International Symposium on Molten Salts*, C. Hussey, D. Newman, G. Mamantov, and Y. Ito, Eds., *Proceedings Volume 94-13*, pgs. 336-342, The Electrochemical Society, Pennington, NJ (1994).
134. Richard T. Carlin and Robert A. Osteryoung, "A Silane-Imidazole Electroactive Film for Battery Cathodes," *Proceedings of Ninth International Symposium on Molten Salts*, C. Hussey, D. Newman, G. Mamantov, and Y. Ito, Eds., *Proceedings Volume 94-13*, pgs. 744-751, The Electrochemical Society, Pennington, NJ (1994).
135. Robert A. Mantz, Paul C. Trulove, Richard T. Carlin, and Robert A. Osteryoung, "ROESY NMR of Basic Ambient-Temperature Chloroaluminate Ionic Liquids", *Inorg. Chem.*, **34**, 3846-3847 (1995).
136. J. Fuller, R. A. Osteryoung, and R. T. Carlin, "Rechargeable Lithium and Sodium Anodes in Chloroaluminate Molten Salts Containing Thionyl Chloride", *J. Electrochem. Soc.*, **142**, 3632-3636 (1995).

AFOSR Contract F49620-96-1-0097, 1 March, 1996 - 31 October, 1999.

137. J. Fuller, R. T. Carlin, and R. A. Osteryoung, "In-Situ Optical Microscopy Investigations of Lithium and Sodium Film Formation in Buffered Room Temperature Molten Salts," *J. Electrochem. Soc.*, **143**, L45 (1996).
138. Richard T. Carlin, Paul C. Trulove, Robert A. Mantz, John J. O'Dea and Robert A. Osteryoung, "Electron Transfer Kinetics for Weakly-Bonded Labile Metal-Ligand Complexes," *Royal Society of Chemistry, Faraday*

139. Robert A. Mantz, Paul C. Trulove, Richard T. Carlin, and Robert A. Osteryoung, "Gutmann Acceptor Properties of LiCl, NaCl, and KCl Buffered Ambient-Temperature Chloroaluminate Ionic Liquids," Proceedings of Tenth International Symposium on Molten Salts, R. T. Carlin, S. Deki, M. Matsunaga, D.S. Newman, J. R. Selman and G. R. Stafford, Eds., Proceedings Volume 96-7, pgs. 104-115, The Electrochemical Society, Pennington, NJ (1996).
140. Dawn King and Robert A. Osteryoung "Acidity of HCl in Neutral Buffered Chloroaluminate Molten Salts," , Proceedings of Tenth International Symposium on Molten Salts, R. T. Carlin, S. Deki, M. Matsunaga, D.S. Newman, J. R. Selman and G. R. Stafford, Eds., Proceedings Volume 96-7, pgs. 80-91, The Electrochemical Society, Pennington, NJ (1996)
141. Acidity of HCl in Neutral Buffered Chloroaluminate Molten Salts, Dawn King, Robert Mantz, and Robert A. Osteryoung, J. Am. Chem. Soc., 118, 11933-11938 (1996).
142. Gutmann Acceptor Properties of LiCl, NaCl, and KCl Buffered Ambient Temperature Chloroaluminate Ionic Liquids, Robert A. Mantz, Paul C. Trulove, Richard T. Carlin, Terry L. Theim, and Robert A. Osteryoung, Inorg. Chem., 36, 1227-1232 (1997).
143. The Room Temperature Ionic Liquid 1-Ethyl-3-Methylimidazolium Tetrafluoroborate: Electrochemical Couples and Physical Properties, Joan Fuller, Richard Carlin , and Robert A. Osteryoung J. Electrochem. Soc., 144, 3881-3886 (1997).
144. Anodization and Speciation of Magnesium in Chloride-Rich Room-Temperature Ionic Liquids, Joan Fuller, Richard T. Carlin, Peter Koronaios, Robert Mantz, and Robert A. Osteryoung, J. Electrochem. Soc., 145, 24-28, (1998).
145. Studies on the Acidity of Neutral Buffered 1-Ethyl-3-Methylimidazolium – AlCl₃ Ambient Temperature Molten Salts, Peter Koronaios, Dawn King, and Robert A. Osteryoung, Inorg. Chem. 37, 2028-32 (1998).
146. Peter Koronaios and Robert A. Osteryoung, "Alkaline Earth Chlorides as Buffering Agents for Ambient Temperature Chloroaluminate Molten Salts," Proceedings of Eleventh International Symposium on Molten Salts, P.C. Trulove, H. C. De Long, G. R. Stafford, and S. Deki, Eds., Proceedings Volume 98-11, pgs. 244-251, The Electrochemical Society, Pennington, NJ (1998).
147. Robert Mantz, Jack Summers, and Robert A. Osteryoung, "Behavior of Oxide Containing Chloroaluminate Molten Salt, Proceedings of the Eleventh International Symposium on Molten Salts, P.C. Trulove, H. C. De Long, G. R. Stafford, and S. Deki, Eds., Proceedings Volume 98-11, pgs. 231-243, The Electrochemical Society, Pennington, NJ (1998).

148. CaCl_2 and MgCl_2 as Buffering Agents for Room-Temperature Chloroaluminate Ionic Liquids, Peter Koronaos and Robert A. Osteryoung, J. Electrochem. Soc., 146, 2995-2999 (1999).
149. Robert A. Osteryoung, "Buffered Chloroaluminate Melts and Latent Acidity," Proceedings of the Twelfth International Symposium on Molten Salts, P.C. Trulove, H. C. De Long, G. R. Stafford, and, Eds., Proceedings Volume, The Electrochemical Society, Pennington, NJ (2000), Proceedings Volume, 99-41, pgs. 12-19, The Electrochemical Society, Pennington, NJ (2000).
150. Diffusion Coefficients of Ferrocene in Composite Materials Containing Ambient Temperature Ionic Liquids, Marek Kosmulski, Robert A. Osteryoung, and Malgorzata Ciszowska, J. Electrochem. Soc., 147, 1454-1458 (2000).
151. Use of the $\text{Ag}/\text{AgCl}/\text{Cl}^-$ Electrode to Estimate Solubility Products in Ambient Temperature Ionic Liquids, Peter Koronaos and Robert A. Osteryoung, J. Electrochem Soc., 147, 3414-19 (2000).

AFOSR Contract F49620-00-1-0061, December 1, 1999 through January 31, 2004

152. Robert A. Mantz, Hugh C. De Long, Robert A. Osteryoung, and Paul C. Trulove, "Studies of Cation Transport in Molten Salts and Molten Salt-Polymer Gels by Pulse-Field Gradient Spin-Echo NMR, Proceedings of the Twelfth International Symposium on Molten Salts, P.C. Trulove, H. C. De Long, G. R. Stafford, and, S. Deki, Eds., Proceedings Volume, 99-41, pgs. 169-176, The Electrochemical Society, Pennington, NJ (2000).
153. Electrochemical Properties of Alkali Metals in 1-Butyl-3-Methylimidazolium Hexafluorophosphates, Deborah L. Boxall and Robert A. Osteryoung, J. Electrochem. Soc., 149, E185-188 (2002).
154. Apparent Anomaly During Rotating Disk Voltammetry in Ionic Liquids, Deborah L. Boxall, John J.O'Dea, and Robert A. Osteryoung, , J. Electrochem. Soc., 149 E468-E471 (2002).
155. "Switching Potentials and Conductivity of Polypyrrole Films Prepared in the Ionic Liquid 1-Butyl-3-Methylimidazolium Hexafluorophosphate," Deborah L. Boxall and Robert A. Osteryoung, J. Electrochem. Soc., 151, e41-45, (2004).

APPENDIX B

Presentations at Meetings Related to Activities on Grant No.F49620-00-1-0061
Studies in Buffered Chloroaluminate Ionic Liquids
December 1, 1999 through January 31, 2004

Invited Presentations

Robert A. Osteryoung, "Ambient Temperature Chloroaluminate Ionic Liquids: An Overview," Keynote Address, International Society of Electrochemistry, Warsaw, Poland, September 2000.

Robert A. Osteryoung, "An Overview of Chloroaluminate Ionic Liquids," Foster Chemistry Colloquium Speaker, SUNY-Buffalo, October 27, 2001.

Deborah L. Boxall and R. A. Osteryoung, "Electrochemical Investigations in the Ionic Liquid 1-Butyl-3-Methylimidazolium Hexafluorophosphate," 13th International Symposium on Molten Salts, The Electrochemical Society, Philadelphia, PA, May, 2002.

Contributed Presentations

D.L Boxall, J.J. O'Dea and R.A. Osteryoung, "Determination of Conductive Polymer Switching Potentials by Rotating Ring-Disk Voltammetry," Southeast Regional Meeting of the American Chemical Society, October 2002, Charleston.

APPENDIX C

Honors and Awards to PI during period of AFOSR support.

- Distinguished Service Award, Colorado State University, 1975.
- American Chemical Society Colorado Section Award, 1978.
- Elected Fellow, American Association for the Advancement of Science, 1980.
- Winner of C. N. Reilley Award in Electroanalytical Chemistry, 1987
- Awarded Schoellkopf Medal, Western New York Section, American Chemical Society 1990
- Elected as Fellow, The Electrochemical Society, 1990-
- Recipient of the American Chemical Society, Division of Analytical Chemistry, Award in Electrochemistry 1991.
- Recipient of the Physical Electrochemistry Division of the Electrochemical Society Max Bredig Award in Molten Salt Chemistry, 1991
- Outstanding Alumnus of the Year Award, College of Arts and Sciences, Ohio University, 1992